Nanoscale Vacuum Electronics: Back to the Future?

Completed Technology Project (2012 - 2013)

Project Introduction

This CIF project developed nanoscale vacuum devices for potential radiation-immune electronics ideal for space applications. Vacuum is superior to any semiconductor since electrons do not get scattered as in semiconductors and consequently the electron velocity is the highest. In addition, the absence of charge carriers makes the device immune to radiations and high temperature which are highly attractive for space electronics. The key to making vacuum electronics practical is to make them nanoscale so that the voltage can be scaled down to below 5 volts, preferably even below 2 volts. Note that even microscale vacuum tubes operate at over 50 volts, hindering their wide use. In addition, the use of standard semiconductor manufacturing processes will help to produce devices on a large scale, thus gaining the cost advantage of the silicon era.

We have made substantial progress in making the nano vacuum devices. We have successfully made the emitter-collector gap of 100 nm using a novel plasma ashing process. It is important to note that we have not used any expensive e-beam lithography to achieve this gap. We have characterized the fabricated devices using a parametric analyzer and evaluated the current-voltage characteristics. The operating voltage has been reduced to 7 V. For devices with a slightly larger gap of 150 nm, the cut-off frequency was found to be 450 GHz, already exceeding the values of state-of-the-art silicon chips with 32 nm gap. Finally, we have successfully co-fabricated a conventional MOSFET on the same chip along with the nano vacuum device (side-by-side). This is for many reasons: 1. To prove, this is standard silicon technology, allowing cost advantages. 2. Actual circuits may use multiple types of devices besides resistors, capacitors and interconnects and thus, it is good proof that our process can simultaneously fabricate multiple types of devices.

Anticipated Benefits

It will benefit all NASA funded missions that require electronic devices.

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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

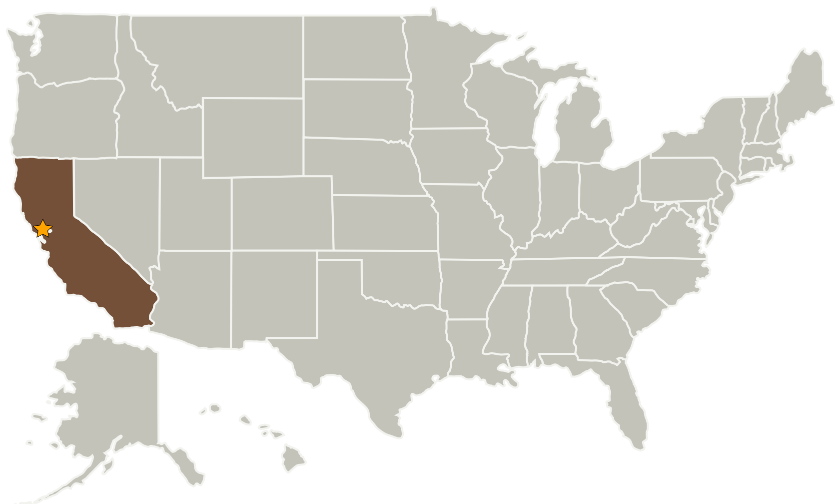
Lead Center / Facility:

Ames Research Center (ARC)

Responsible Program:

Center Innovation Fund: ARC CIF

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Ames Research Center(ARC)	Lead Organization	NASA Center	Moffett Field, California

Primary U.S. Work Locations
California

Stories

1676 Approval from Ames (#17536 and 25725)
(https://techport.nasa.gov/file/8747)

Cofabrication of Vacuum Field Emission Transistor (VFET) and MOSFET
(https://techport.nasa.gov/file/2385)

Vacuum Nanoelectronics: Back to the Future? - Gate Insulated Nanoscale Vacuum Transistor
(https://techport.nasa.gov/file/1707)

Project Management

Program Director:
Michael R Lapointe

Program Manager:
Harry Partridge

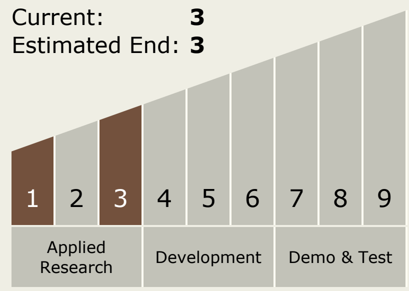
Project Manager:
M Meyyappan

Principal Investigator:
M Meyyappan

Co-Investigator:
Jin-woo Han

Technology Maturity (TRL)

Start: **1**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  - └ TX08.1 Remote Sensing Instruments/Sensors
    - └ TX08.1.1 Detectors and Focal Planes